Non-volatile memory

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Non-volatile memory, **nonvolatile memory**, **NVM** or **non-volatile storage**, is computer memory that can retain the stored information even when not powered. Examples of non-volatile memory include read-only memory, flash memory, most types of magnetic computer storage devices (e.g. hard disks, floppy disk drives, and magnetic tape), optical disc drives, and early computer storage methods such as paper tape and punch cards.

Non-volatile memory is typically used for the task of secondary storage, or long-term persistent storage. The most widely used form of primary storage today is a volatile form of random access memory (RAM), meaning that when the computer is shut down, anything contained in RAM is lost. Unfortunately, most forms of non-volatile memory have limitations that make them unsuitable for use as primary storage. Typically, non-volatile memory either costs more or performs worse than volatile random access memory.

Several companies are working on developing non-volatile memory systems comparable in speed and capacity to volatile RAM. For instance, IBM is currently developing MRAM (Magnetic RAM). Not only would such technology save energy, but it would allow for computers that could be turned on and off almost instantly, bypassing the slow start-up and shutdown sequence.

Memory types

Volatile

- DRAM
- eDRAM
- SRAM
- 1T-SRAM
- Upcoming
  - Z-RAM
  - TTRAM

Non-Volatile

- Flash memory
- ROM
  - PROM
  - EPROM
  - EEPROM
- Upcoming
  - FeRAM
  - MRAM
  - PRAM
  - SONOS
  - RRAM
  - NRAM

Non-volatile data storage can be categorised in electrically addressed systems random access memory and mechanically addressed systems hard disks, optical disc, magnetic tape, Holographic memory and such. Electrically addressed systems are expensive, but fast, whereas mechanically addressed systems have a low price per bit, but are slow. Non-volatile memory may one day eliminate the need for comparatively slow forms of secondary storage systems, which include hard disks.

Contents

Exhibit B

Electrically addressed

Electrically addressed non-volatile memories based on charge storage can be categorised according to their write mechanism:

Mask-programmed ROM

One of the earliest forms of non-volatile read-only memory, the mask-programmed ROM was prewired at the design stage to contain specific data; once the mask was used to manufacture the integrated circuits, the data was cast in stone (or at least in silicon) and could not be changed. Whatever 1's and 0's were in memory when it left the factory were there for life.

The mask ROM was therefore useful only for large-volume production, such as for read-only memories containing the startup code in early microcomputers. This programme was often referred to as the "bootstrap", as in pulling oneself up by one's own bootstraps.

Due to the very high initial cost and inability to make revisions, the mask ROM is rarely if ever used in new designs.

Programmable ROM

See main article Programmable read-only memory.

The next approach was to create a chip which was initially blank; the programmable ROM originally contained silicon or metal fuses, which would be selectively "blown" or destroyed by a device programmer or PROM programmer in order to change 0's to 1's. Once the bits were changed, there was no way to restore them to their original condition. Still non-volatile but still somewhat inflexible.

Early PAL programmable array logic chips used a similar programming approach to that used in the fuse-based PROMs.

In most new designs, eraseable memories or one-time programmable chips have replaced the old fuse PROMs.

Erasable PROMs

See main article EPROM.

There are two classes of non-volatile memory chips based on EPROM technology.

UV-erase EPROM

The original erasable non-volatile memories were EPROM's; these could be readily identified by the distinctive quartz window in the centre of the chip package. These operated by trapping an electrical charge on the gate of a field-effect transistor in order to change a 1 to a 0 in memory. To remove the charge, one would place the chip under an intense short-wavelength fluorescent ultraviolet lamp for 20-30 minutes, returning the entire chip to its original blank (all ones) state.

OTP (one-time programmable) ROM

An OTP is electrically an EPROM, but with the quartz window physically missing. Like the fuse PROM it can be written once, but cannot be erased. It has largely replaced PROM chips in electronic production as an EPROM with no window is inexpensive to manufacture and can be programmed using identical equipment to that used to write to the UV-window EPROM.

Electrically erasable PROM

See main article EEPROM.

Electrically erasable PROM's have the advantage of being able to selectively erase any part of the chip without the need to erase the entire chip and without the need to remove the chip from the circuit. While an erase and rewrite of a location appears nearly instantaneous to the user, the write process is slightly slower than the read process; the chip can be read at full system speeds.

The limited number of times a single location can be rewritten is usually in the 10000-100000 range; the capacity of an EEPROM also tends to be smaller than that of other non-volatile memories. Nonetheless, EEPROMs are useful for storing settings or configuration for devices ranging from dial-up modems to satellite receivers.

Flash memory

See main article Flash memory.

The flash memory chip is a close relative to the EEPROM; it differs in that it can only be erased one block or "page" at a time. Capacity is substantially larger than that of an EEPROM, making these chips a popular choice for digital cameras and desktop PC BIOS chips.

Battery-backed static RAM

See main article Nonvolatile BIOS memory.

This is a volatile memory chip (which loses its data if power is removed) to which a battery has been added in order to preserve the contents in the absence of external power. These used to be typically manufactured with CMOS technology to minimise power consumption; a lithium cell can easily power a small memory for a few years. It is now common to use SDRAM with a Lithium ion battery; it is possible to preserve a gigabyte of such memory for days. The settings from the BIOS menus which appear on startup on most desktop PCs are stored in battery-backed CMOS static RAM as a battery must already be present on the mainboard to keep the real-time clock running when the computer is not in use.

An example of this is seen in video game consoles that allow you to save your games onto the cartridges, such as the Nintendo 64 or the Game Boy.

See also

- NVRAM Should everything in the NVRAM category be moved from this article to the NVRAM article: Flash, EEPROM, MRAM, etc.

Mechanically addressed systems

Tape

See main article Magnetic tape.

Hard disk

See main article Hard disk.

Optical disk

See main article Optical disc.

Nanodrive

See main article IBM Millipede.

Holographic storage

See main article Holographic memory.

Specifications

Include table with specifications (Data density, capacity, price per bit, price per unit, data rate, access time, power consumption, form factor) of Flash, Hard disc (2.5", 1"), Tape, DVD, MRAM, NanoDrive and Holographic Disc . Table will be kept up to date on a yearly basis

A justification for this table can be found here:

IP Suppliers: Non-Volatile Memory

Impinj, Inc. - a leading semiconductor and RFID company that provides logic nonvolatile memory

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